CHAPTERS 800 - 890 HIGHWAY DRAINAGE DESIGN

CHAPTER 800 - GENERAL ASPECTS

Topic 801 - General

Index 801.1 - Introduction

This section is not a textbook, and is not a substitute for fundamental engineering knowledge or experience.

The fields of hydrology and the hydraulics of highway drainage are rapidly evolving and it is the responsibility of the engineer to keep abreast of current design practices. As new practices or procedures are adopted by the Department, this section will be updated.

Instructions for the design of highway drainage features provided are for information and guidance of Department employees. Drainage policies, procedures and standards given are subject to amendment as conditions warrant and are neither intended as, nor do they establish, legal standards. Special situations may call for variations from these requirements, subject to approval of the Office of Project Planning and Design or approval by others as may be specifically referenced.

801.2 Drainage Design Philosophy

Highway drainage design is much more than the mere application of the technical principles of hydrology and hydraulics. Good drainage design is a matter of properly balancing technical principles and data with the environment giving due consideration to other factors such as safety and economics. Such design can only be accomplished through the liberal use of sound engineering judgment. Drainage features to remove runoff from the roadway and to convey surface and stream waters originating upstream of the highway to the downstream side should be designed to accomplish these functions without causing objectionable backwater, excessive velocities or unduly affecting traffic safety. A goal in highway drainage design should be to perpetuate natural drainage, insofar as practical.

801.3 Drainage Standards

Drainage design criteria should be selected that are commensurate with the relative importance of the highway, associated risks, and possible damage to adjacent property. The objective of drainage design should be to provide optimum facilities considering function versus cost rather than to just meet minimum standards.

Engineers, and other professional disciplines using this guide must recognize that hydrologic analysis, as practiced by the highway engineer, has not advanced to the level of precise mathematical expression. All hydrologic analysis methods, whether deterministic or statistical, are based on the information available. A common problem faced by the highway design engineer is that there maybe insufficient flow data, and often no data at all, at the site for which a stream crossing is to be designed. By applying analytical principles and methods it is possible to obtain peak discharge estimates which are functionally acceptable for the design of highway drainage structures and other features.

The design of highway drainage structures and other features must consider the probability of flooding and provide protection which is commensurate with the importance of the highway, the potential for property damage, and traffic safety. Traditionally, the level of assurance for such protection has been specified in terms of the peak rate of flow during passage of a flood or storm of the severity associated with the frequency of occurrence, i.e. a 10-year storm, the 50-year flood, etc. State-of-the-art methods and procedures associated with the necessary hydrologic analysis required to determine the severity and probability of occurrence of possible rare storms and flood events are inherently ambiguous. Therefore, the suggested drainage design criteria relating to frequency of occurrence references in this manual are provided for guidance only and are not intended to establish either legal or design standards which must be strictly adhered to. Rather, they are intended as a starting point of reference for designing the most cost effective drainage structures and facilities considering the

importance of the highway, safety, legal obligations, ease of maintenance, and aesthetics.

801.4 Objectives of Drainage Design

Drainage design seeks to prevent the retention of water by the highway and provide for removal of water from the roadway through a detailed analysis considering all pertinent factors.

Specific steps to be taken generally include:

(a) Estimating the amount and frequency of storm runoff.

(b) Determining the natural points of concentration and discharge, the limiting elevations of entrance head, and other hydraulic controls.

(c) Estimating the amount and composition of bedload and its abrasive and bulking effects.

(d) Determining the necessity for protection from floating trash and from debris moving under water.

(e) Determining the requirements for energy dissipation and bank protections.

(f) Determining the necessity of providing for the passage of fish and recognizing other ecological conditions and constraints. Water quality and pollution control are discussed under Index 110.2. Aspects of wetlands protection are covered under Index 110.4.

(g) Analyzing the deleterious effects of corrosive soils and waters on structures.

(h) Comparing and coordinating proposed design with existing drainage structures and systems handling the same flows.

(i) Coordinating, with local agencies, proposed designs for facilities on roads to be relinquished.

(j) Providing access for maintenance operations.

(k) Providing for removal of detrimental amounts of subsurface water.

(l) Designing the most efficient drainage facilities consistent with the factors listed above, economic considerations, the importance of the highway, ease and economy of maintenance, safety, legal obligations, and aesthetics.

(m) Checking the structural adequacy of designs by referral to the Division of Structures or by use of data furnished by the Division of Structures.

801.5 Economics of Design

An economic analysis of alternate drainage designs, where a choice is available, should always be made. Non-engineering constraints may severely limit the design alternatives available to the drainage design engineer for a specific project or location. Generally, however, the design engineer has a wide range of materials and products to choose from in selecting the most economical design from available alternatives for highway drainage structures and other features.

The following factors should be considered in the selection of alternative designs and economic comparisons:

(a) Initial cost of construction and right of way.

(b) Evaluation of flood related risks to the highway and to adjacent properties including potential liabilities for damage.

(c) Cost of detours and traffic handling.

(d) Service life of the highway and of the drainage structure.

(e) Cost of providing traffic safety features.

(f) Aesthetics.

(g) Costs to traveling public for delays or extra travel distance due to road closures.

(h) Initial cost versus maintenance costs for cleanout, repair, traffic control and other pertinent maintenance charges that may be incurred during the life of the facility.

(i) Inlet and outlet treatment.

801.6 Use of Drainage References

No attempt has been made herein to detail basic hydrologic and hydraulic engineering techniques.

Various sources of information, including FHWA Hydraulic Engineering Circulars

(HEC's); Title 23, Code of Federal Regulations (CFR), Part 650, Subpart A; AASHTO Guidelines; Federal-Aid Policy Guide and numerous hydrology and hydraulics reports and texts have been used to compile this highway drainage guide. Frequent references are made to these publications. Where there is a conflict in information or procedure, engineers must look at all pertinent parameters and use their best judgment, to determine which approach is the most consistent with the objectives of Caltrans drainage design principles and which most closely relates to the specific design problem or project.

Topic 802 - Drainage Design Responsibilities

802.1 Functional Organization

(1) State and Local Project Development Program. The Highway Drainage Design Coordinators Branch in the Office of Project Planning and Design, State and Local Project Development Program performs the following functions under the direction of the Headquarters Hydraulics Engineer:

(a) Provide design information, guidance and standards to the Districts for the design of surface and subsurface drainage.

(b) Keep informed on the latest data from research, experimental installations, other public agencies, and industry that might lead to improvement in drainage design practices.

(c) Promote statewide uniformity of design procedures, and the exchange of information between Districts.

(d) Coordinate drainage design practices with other Caltrans Offices.

(e) Review special drainage problems and unusual drainage designs on the basis of statewide experience.

(f) Act in an advisory capacity to the Districts when requested.

(2) Engineering Services Center. The Engineering Services Center is responsible for:

(a) The hydraulic design of bridges, bridge deck drains, and special culverts.

(b) The structural adequacy of all drainage facilities.

(c) The adequacy of pumping plant characteristics and temporary storage. Refer to Topic 839 for further discussion on pumping stations.

(d) Compliance with Federal-Aid Policy Guide, Transmittal 1, G 6012.1 and submittal of preliminary hydraulic data as outlined under Topic 805.

(e) Geotechnical (soil mechanics and foundation engineering) considerations.

(3) Legal Division. The Legal Division provides legal advice and guidance to other Caltrans Offices concerning the responsibilities of the Department and owners of property along State highways with regard to surface water drainage.

(4) Districts. The District Director is responsible for:

(a) The hydrology for all drainage features except bridges.

(b) The hydraulic adequacy of all drainage features, except bridges and any special culverts and appurtenances designed by the Division of Structures.

(c) Consulting with the Division of Structures when it is proposed that an existing bridge be replaced with a culvert.

(d) Bank and shore protection designs, including erosion protection measures at ends of bridges and other structures designed by the Division of Structures.

(e) Assigning one or more engineers in responsible charge of hydrologic study activities and the hydraulic design of drainage features.

(f) Compliance with Federal-Aid Policy Guide, Transmittal 1, G 6012.1 for storm drain systems.

(g) Providing additional staff as necessary with the training and background required to perform the following:

- Accomplish the objectives of drainage design as outlined under Index 801.4
- Prepare drainage plans or review plans prepared by others.
- Study drainage problems involving cooperative agreements and make recommendations to the decision makers.
- Accumulate and analyze hydrologic and hydraulic data reflecting the local conditions throughout the District for use in design.
- Review drainage changes proposed during construction.
- Make investigations and recommendations on drainage problems arising from the maintenance of existing State highways.
- Coordinate drainage design activities with other District Offices and Branches.
- Coordinate drainage designs with flood control districts and other agencies concerned with drainage by representing the District at meetings and maintaining an active liaison with these agencies at all times.
- Furnish data as required on special problems, bridges, large culverts, culverts under high fills and pumping plants that are to be designed by the Division of Structures.
- Make field inspections of proposed culvert sites, existing drainage structures during storms, and storm damage locations.
- Document condition and file data that might forestall or defend future lawsuits.
- Review permits for drainage facilities to be constructed by other agencies or private parties within the highway right of way.
- Investigate and prepare responses to complaints relative to drainage conditions on or adjacent to the right of way.

Assignment of the duties described above will vary between districts. Due to the increasing complexity of hydraulic and hydrologic issues it is imperative that the more complex analyses be performed by experienced hydraulic designers. To provide guidance on those issues where district hydraulic units should become involved, the following list is provided.

- Storm drain design and calculations.
- Drainage basins exceeding 1.3 km^2.
- Hydrograph development or routing.
- Open channel modification or realignment.
- Retention or detention basins.
- Backwater analysis.
- High potential for flood damage litigation.
- Scour analysis or sediment transport (typically forwarded to DOS).
- Culvert designs greater than 900 mm in diameter.
- Encroachments on FEMA designated floodplains.
- Modifications to inlet or outlet capacities on existing culverts or drainage inlets (e.g., placement of safety end grates, conversion of side opening inlets to grated inlets, etc.).
- Unique hydraulic design features (e.g., energy dissipator design, pumping stations, siphons, etc.).

This list is not all inclusive, and many additional functions are likely to be performed by hydraulic units. Although various constraints may preclude the hydraulic unit from actively performing the design or analysis of these items, a thorough review by that unit should be performed, at a minimum.

(5) *Office of Materials Engineering and Testing Services*. METS provides advice and guidance to other Caltrans Offices and Branches concerning:

(a) Service life, physical properties, and structural adequacy of materials used in drainage design.

(b) Water quality considerations.

802.2 Culvert Committee

The Caltrans Culvert Committee is composed of nine members representing the Offices of Project Planning and Design, Structure Design, Office Engineer, and Materials Engineering and Testing Services, along with the Construction Program and Maintenance Program. The Committee is chaired by the Headquarters Hydraulics Engineer in the Office of Project Planning and Design. The Committee performs the following functions:

(a) Investigates new materials and new installation methods that may improve the economic service life of culverts and other drainage facilities.

(b) Coordinates drainage design practice with other headquarters departments.

(c) Follows current research and takes steps to implement successful findings.

(d) Acts as an advisory group to Districts and other Caltrans Offices when requested.

(e) Serves as Caltrans liaison with manufacturers, suppliers, contractors and industry associations.

The authority of the Committee is advisory only, and recommendations of the Committee are submitted to the Chief, Office of Project Planning and Design for approval and implementation through design guidelines and standards.

Requests for consideration of new materials, methods, or procedures should be directed to the Committee Chairman.

802.3 Joint Bank Protection Committee

The Caltrans Joint Bank Protection Committee is composed of representatives from the Division of Structures, Project Planning and Design, Materials Engineering and Testing Services, Construction Program, and Maintenance Program. It is chaired by the Division of Structures representative.

The Committee performs the following functions:

(a) Acts as a service and an advisory group available to Districts and Caltrans Offices and Branches upon written request for special investigations or study. Requests for investigation of rock slope protection, channel or bridge protection, major channel changes, etc. should be directed to the Chairman of the Committee.

(b) Supplements or modifies bank and shore protection practice publications as warranted.

(c) Investigates, develops, and implements more detailed design criteria for the various types of bank and shore protection.

(d) Observes performances of existing installations during or following severe exposures. The Districts or Caltrans Offices or Branches are requested to inform the Chairman, Joint Bank Protection Committee, or any available members of the Committee, of damage to installations by flood or high seas.

Topic 803 - Drainage Design Policies

803.1 Basic Policy

In drainage design, the basic consideration is to protect the highway against damage from storm and subsurface waters, taking into account the effect of the proposed improvement on traffic and property. Unless the State would benefit

thereby, or the cost is borne by others, no improvement in the drainage of areas outside the right of way is to be considered on Caltrans projects.

803.2 Cooperative Agreements

The extent of the department's financial participation in cooperative drainage improvement projects must be commensurate with the benefits to the Department and the traveling public.

(1) Local Agencies. Caltrans may participate with Local Agencies, Flood Control Districts or Drainage Assessment Districts on drainage improvement projects. Such projects must be covered by a formal agreement prepared and processed in accordance with instructions in the Caltrans Cooperative Agreement Manual.

(2) Federal and State Flood Control Projects. The cost of upgrading or modifying existing State highway facilities to accommodate Federal and/or State funded flood control projects is normally the responsibility of the agency funding the project. As necessary, Caltrans may enter into agreements containing provisions that the cost of betterments to existing highways, including drainage features, will be paid for by the Department. The Cooperative Agreement Manual contains procedures for preparing interagency agreements.

803.3 Up-Grading Existing Drainage Facilities

(1) Rehabilitation and Reconstruction Projects. The hydraulic adequacy, as well as the structural adequacy of existing drainage facilities should be evaluated early in the project development process on pavement rehabilitation and highway reconstruction projects.

Repair or replacement of structurally deficient drainage structures and up-grading of hydraulically inadequate drainage facilities should, whenever practicable, be included in the work of the proposed project. A thorough investigation of upstream and downstream conditions is often required to reveal what adverse effects there may be with increasing the capacity or velocity of existing cross drainage.

A cooperative agreement should be negotiated when the proposed work includes the upgrading of an existing storm drain system under the jurisdiction of a local or other public agency.

(2) Proposed Upstream Development. Unless developers of land in the drainage basin upstream of existing State highways incorporate positive stormwater management practices, such as detention or retention storage basins within their improvement areas, the peak flow from stormwater runoff is nearly always increased. As a practical matter, minor increases in peak flow are usually not objectionable. However, uncontrolled upstream development or diversions can significantly increase the peak flow run-off causing the passable capacity of the downstream drainage systems, including existing highway culverts, to be exceeded.

When reasonable solutions to potential drainage problems associated with such increased flows include the up-grading of drainage facilities within the State highway right-of-way, cooperative agreements with the responsible local agency should be negotiated. The local agency having permit authority has the responsibility for assessing liabilities and seeking commensurate funding for mitigation of run-off impacts from the developers. The local agency should not allow potentially harmful developments to proceed until all issues have been resolved. If it becomes apparent that the District, the local agency and the developer may not amiably reach agreement, the matter should be referred to Caltrans Legal Division before there is an impasse in the negotiations.

Caltrans financial participation in such drainage improvements must be based on the general rule stated in Index 803.2 Cooperative Agreements.

(3) Hydraulically Inadequate Facilities. Land use changes nearly always cause areas to become less pervious and drainage basins to yield greater volumes and increase peak stormwater run-off flows. Even development of a small parcel of land within

a drainage basin causes some increase in stormwater run-off. Individually the increase may be negligible. Collectively these incrementally small increases over time may cause the design capacity of an existing culvert to be exceeded.

The up-grading of this category of hydraulically inadequate drainage facilities may be partially or fully financed by Caltrans. Only if the benefit cost (b/c) ratio is equal to or greater than one is up-grading viable for normal Caltrans project funding. When the benefits to the Department and the traveling public do not justify increasing the capacity, up-grading may still be accomplished cooperatively with the local agency in accordance with the general rule for participation under Index 803.2 Cooperative Agreements.

Topic 804 - Floodplain Encroachments

804.1 Purpose

The purpose of these instructions is to provide uniform procedures and guidelines for Caltrans multi-disciplinary evaluation of proposed highway encroachments on floodplains.

804.2 Authority

Title 23, CFR, Part 650, Subpart A, prescribes FHWA's "...policies and procedures for the location and hydraulic design of highway encroachments on floodplains, ...".

804.3 Applicability

These provisions apply to any Federally approved highway construction, reconstruction, rehabilitation, repair, or improvement project which affects the (100-year) base floodplain. The only exception is repairs made during or immediately following a disaster. The premise is that all Federal-aid projects be evaluated and that diligent efforts be made to:

- Avoid significant floodplain encroachments where practicable.
- Minimize the impact of highway actions that adversely affect the base floodplain.
- Be compatible with the National Flood Insurance Program (NFIP) of the Federal Emergency Management Agency (FEMA).

804.4 Definitions

The following definitions of terms are made for the purpose of uniform application in the documentation and preparation of floodplain evaluation reports. Refer to Title 23, CFR, Part 650, Section 650.105 for a complete list of definitions.

(1) Base Flood. The flood or tide having a 1 percent chance of being exceeded in any given year (100-year flood).

(2) Base Floodplain. The area subject to flooding by the base flood. Every watercourse (river, creek, swale, etc.) is subject to flooding and theoretically has a base floodplain.

(3) Encroachment. An action within the limits of the base floodplain. Any construction activity (access road, building, fill slopes, bank or slope protection, etc.) within a base floodplain constitutes an encroachment.

(4) Location Hydraulic Study. A term from 23 CFR, Section 650.111 referring to the preliminary investigative study to be made of base floodplain encroachments by a proposed highway action. The extent of investigation and the discussion content in the required documentation of the "Location Hydraulic Study" is very site specific and need be no more than that which is commensurate with the risk(s) and impact(s) particular to the location under consideration. The information developed, documented and retained in the project file is to be the minimum necessary for compliance.

804.5 Procedures

Floodplain evaluations are essentially an extension of the environmental assessment process and instructions contained in the Environmental Handbook and the Project Development Procedures Manual are to be followed. Early in the planning of a project it is necessary to first determine:

(a) If a proposed route alternative will encroach on a base floodplain or,

(b) Where proposed construction on existing highway alignment encroaches on a base floodplain.

804.6 Responsibilities

The District Project Engineer is generally the responsible party for initiating and coordinating the overall multi-disciplinary team activities of evaluation and documentation of floodplain impacts. Discussion of specific hydraulic and environmental aspects are required by 23 CFR 650, Subpart A. Preparing the project floodplain evaluation report and the summary for the environmental document or project report is normally the responsibility of the Environmental Planning Branch. The District Hydraulics Engineer will, as necessary, develop the hydrological and hydraulic information and provide technical assistance for assessing impacts of floodplain encroachments.

804.7 Preliminary Evaluation of Risks and Impacts

Virtually all proposed highway improvements that are considered as floodplain encroachments will be designed to have:

(a) No significant risks associated with implementation and,

(b) Negligible environmental impacts on the base floodplain.

(1) Risks. There will always be some risk, the potential for property damage and flooding that may affect public safety, associated with highway drainage design. In a majority of cases, a field review with a NFIP or USGS map and the application of good engineering judgment are all that is needed to determine if such risks are significant or acceptable.

(2) Impacts. The assessment of potential impacts on the floodplain environment will include:

(a) Impacts on natural and beneficial floodplain values.

(b) Support of probable incompatible floodplain development.

Except for the more environmentally sensitive projects, a single visit to the project site by qualified District personnel, such as the Project Engineer, Hydraulics Engineer, and Environmental Planner, to assess and document the risks and environmental impacts associated with the proposed project is generally all that is necessary to obtain enough information for the "Location Hydraulic Study". Any reasonable adaptation of the floodplain evaluation report summary form, Figure 804.7, may be utilized to document and summarize the findings of the "Location Hydraulic Study" when the project is expected to be processed with a categorical exclusion.

804.8 Design Standards

The design standards for highways encroaching on a floodplain are itemized in 23 CFR, Section 650.115. One requirement often overlooked is the need to asses the costs and risks associated with the overtopping flood for design alternatives in those instances where the overtopping flood exceeds the base flood.

The content of design study information to be retained in the project file are described in 23 CFR, Section 650.117. When in a floodplain, plans shall show pertinent hydraulic information from the FEMA study.

Topic 805 - Preliminary Plans

805.1 Required FHWA Approval

Federal-Aid Policy Guide, Transmittal 1, G 6012.1, dated Dec. 9, 1991, requires Federal Highway Administration (FHWA) approval of preliminary plans for major or unusual bridges, structures and drainage features on the National Highway System.

805.2 Bridge Preliminary Report

A Bridge Preliminary Report will be prepared by the Division of Structures and submitted to the California FHWA Division Office in Sacramento for approval on major, unusual or movable bridges, and vehicular or drainage tunnels.

- Major bridges are bridges having a deck area greater than 11,600 m^2.
- An unusual bridge involves difficult or unique foundation problems, new foundation types, new or complex designs

Figure 804.7

Floodplain Evaluation Report Summary

Dist. _____ Co. _____ Rte._____ K.P._____

Project No. _____ Bridge No._____

Limits _____

_____

Floodplain Description _____

_____

		Yes	No
1.	Is the proposed action a longitudinal encroachment of the base floodplain?	_____	_____
2.	Are the risks associated with the implementation of the proposed action significant?	_____	_____
3.	Will the proposed action support probable incompatible floodplain development?	_____	_____
4.	Are there any significant impacts on natural and beneficial floodplain values?	_____	_____
5.	Routine construction procedures are required to minimize impacts on the floodplain. Are there any special mitigation measures necessary to minimize impacts or restore and preserve natural and beneficial floodplain values? If yes, explain.	_____	_____
6.	Does the proposed action constitute a significant floodplain encroachment as defined in 23 CFR, Section 650.105(q).	_____	_____
7.	Are Location Hydraulic Studies that document the above answers on file? If not explain.	_____	_____

PREPARED BY:

_____ _____
Signature - Dist. Hydraulic Engineer Date

_____ _____
Signature - Dist. Environmental Branch Chief Date

_____ _____
Signature - Dist. Project Engineer Date

I CONCUR:

_____ _____
Signature - FHWA Date

involving unique design or operational features, longer than normal spans or bridges for which the design procedures depart from current acceptable practice. Examples include cable stayed, suspension, arch, segmental concrete bridges, trusses and other bridges which deviate from AASHTO Standard Specifications or Guide Specifications for Highway Bridges, bridges requiring abnormal dynamic analysis for seismic design, bridges designed using a three-dimensional computer analysis, bridges with spans exceeding 150 m, and bridges which include ultra high strength concrete or steel.

805.3 Pumping Stations

The Division of Structures will submit preliminary plans and hydraulic data for storm water pumping facilities to the California FHWA Division Office in Sacramento. FHWA approval is required for storm water pumping facilities designed to discharge more than 0.56 m^3/s.

805.4 Storm Drain Systems

The District will submit preliminary plans and hydraulic data for unusual storm drain systems to the California FHWA Division Office in Sacramento. FHWA approval is required for storm drain systems that carry more than 5.6 m^3/s or have an accumulated surface detention storage system of more than 6150 m^3.

805.5 Unusual Hydraulic Structures

The District will submit preliminary plans and hydraulic data for unusual hydraulic structures to the California FHWA Office in Sacramento. FHWA approval is required for hydraulic structures involving unusual stream stability countermeasures, an atypical or unique design technique or unusual or complex pumping stations or storm drain systems.

805.6 Levees and Dams Formed by Highway Fills

The District will submit preliminary plans and other supportive data to the California FHWA Division Office in Sacramento for approval of:

(a) Highway fills which will function as a levee and serve the purpose of reducing the flooding of adjacent areas.

(b) Dams formed by highway fills which will permanently impound water more than 7.6 m in depth or 61 500 m^3 in volume. See Index 829.9 Dams, for legal definition of a dam and regulations relative to approval by the California Department of Water Resources.

805.7 Geotechnical

The District shall submit preliminary plans and technical data for major or unusual geotechnical features to the California FHWA Division Office for approval. Major geotechnical features include unusually deep cuts or high fills where the site geology is potentially unstable, landslide corrections, and large retaining walls (cantilever, permanent ground anchor, and soil reinforcement). An unusual geotechnical feature involves new or complex retaining wall systems or ground improvement systems.

805.8 Data Provided by the District

The following items of supportive information must be provided with requests for FHWA approval:

(a) Preliminary plans and profiles:

- Approach layouts.
- Drainage plans.

(b) Hydraulic design studies:

- Design Q and frequency.
- Hydraulic grade lines.
- Inflow - Outflow hydrographs.
- Capacity of reservoirs or pump storage systems.
- Pump capacity.
- Stream velocities.
- Water surface profiles.
- Slope protection, toe and top elevations.

(c) Proposed specifications.

(d) Estimated cost.

(e) Foundation report:

- Embankment design for fills functioning as dams.

(f) Subsurface investigations.

(g) Coordination with Federal, state and local agencies.

(h) Other pertinent data.

The FHWA requires that three copies of supportive information be submitted to the California FHWA Division Office with approval requests. Four copies of supportive information are to be furnished to the Division of Structures to prepare the FHWA approval requests for bridges and pumping stations.

Topic 806 - Definitions of Drainage Terms

806.1 Introduction

These definitions are for use with Sections 800 through 890 of this manual and the references cited. They are not necessarily definitions as established by case or statutory law.

See Index 874 for an additional listing of drainage related terms. This separate listing includes those terms particularly applicable to Channel and Shore Protection - Erosion Control.

806.2 Drainage Terms

Accretion. Outward growth of bank or shore by sedimentation. Increase or extension of boundaries of land by action of natural forces.

Action. Any highway construction, reconstruction, rehabilitation, repair, or improvement.

Aggressive. Refers to the corrosive properties of soil and water.

Alluvial. Referring to deposits of silts, sands, gravels and similar detrital material which have been transported by running water.

Alluvium. Stream-borne materials deposited in and along a channel.

Aqueduct. (1) A major conduit. (2) The entire transmission main for a municipal water supply which may consist of a succession of canals, pipes, tunnels, etc. (3) Any conduit for water; especially one for a large quantity of flowing water. (4) A structure for conveying a canal over a river or hollow.

Aquifer. Water-bearing geologic formations that permit the movement of ground water.

Artesian Waters. Percolating waters confined below impermeable formations with sufficient pressure to spring or well up to the surface.

Avulsion. (1) A forcible separation; also, a part torn off. (2) The sudden removal of land from the estate of one man to that of another, as by a sudden change in a river, the property thus separated continuing in the original owner. (3) A sudden shift in location of channel.

Backwater. An unnaturally high stage in stream caused by obstruction or confinement of flow, as by a dam, a bridge, or a levee. Its measure is the excess of unnatural over natural stage, not the difference in stage upstream and downstream from its cause.

Bank. The lateral boundary of a stream confining water flow. The bank on the left side of a channel looking downstream is called the left bank, etc.

Bank Protection. Revetment, or other armor protecting a bank of a stream from erosion, includes devices used to deflect the forces of erosion away from the bank.

Base Flood. The flood or tide having a 1 percent chance of being exceeded in any given year (100-year flood). The "base flood" is commonly used as the "standard flood" in Federal flood insurance studies. (see Regulatory Flood).

Base Floodplain. The area subject to flooding by the base flood.

Bedding. The foundation under a drainage structure.

Bed Load. Sediment that moves by rolling, sliding, or skipping along the bed and is essentially in contact with the stream bed.

Braided Stream. A stream in which flow is divided at normal stage by small islands. This type of stream has the aspect of a single large channel with which there are subordinate channels.

Bulking. The increase in volume of flow due to air entrainment, debris, bedload, or sediment in suspension.

Camber. An upward adjustment of the profile of a drainage facility under a heavy loading (usually a high embankment) and poor soil conditions, so that as the drainage facility settles it approaches the design profile.

Capacity. The effective carrying ability of a drainage structure. Generally measured in cubic meters per second.

Capillarity. The attraction between water and soil particles which cause water to move in any direction through the soil mass regardless of gravitational forces.

Capillary Water. Water which clings to soil particles by capillary action. It is normally associated with fine sand, silt, or clay, but not normally with coarse sand and gravel.

Catch Basin. A drainage structure which collects water. May be either a structure where water enters from the side or through a grating.

Check Dam. A small dam generally placed in steep ditches for the purpose of reducing the velocity in the ditch.

Cienega. A swamp formed by water rising to the surface at a fault.

Cleanout. An access opening to a roadway drainage system. Usually consists of a manhole shaft, a special chamber or opening into a shallow culvert or drain.

Coefficient of Runoff. Percentage of gross rainfall which appears as runoff.

Composite Hydrograph. A plot of mean daily discharges for a number of years of record on a single year time base for the purpose of showing the occurrence of high and low flows.

Concentrated Flow. Flowing water that has been accumulated into a single fairly narrow stream.

Concentration. In addition to its general sense, means the unnatural collection or convergence of waters so as to discharge in a narrower width, and at greater depth or velocity.

Conduit. Any pipe, arch, box or drain tile through which water is conveyed.

Confluence. A junction of streams.

Contraction. The reduction in cross sectional area of flow.

Control. A section or reach of an open conduit or stream channel which maintains a stable relationship between stage and discharge.

Conveyance. A measure of the water carrying capacity of a stream or channel.

Cradle. A concrete base generally constructed to fit the shape of a structure which is to be forced through earthen material by a jacking operation. The cradle is constructed to line and grade. Then the pipe rides on the cradle as it is worked through the given material by jacking and tunneling methods. Also serves as bedding for pipes in trenches in special conditions.

Critical Depth. (Depth at which specific energy is a minimum) - The depth of water in a conduit at which under certain other conditions the maximum flow will occur. These other conditions are the conduit is on the critical slope with the water flowing at its critical velocity and there is an adequate supply of water. The depth of water flowing in an open channel or a conduit partially filled, for which the velocity head equals one-half the hydraulic mean depth.

Critical Flow. That flow in open channels at which the energy content of the fluid is at a minimum. Also, that flow which has a Froude number of one.

Critical Slope. That slope at which the maximum flow will occur at the minimum velocity. The slope or grade that is exactly equal to the loss of head per meter resulting from flow at a depth that will give uniform flow at critical depth; the slope of a conduit which will produce critical flow.

Critical Velocity. Mean velocity of flow when flow is at critical depth.

Culvert. A closed conduit, other than a bridge, which allows water to pass under a highway. A culvert has a span of less than 6.1 m, or if multispan, the individual spans are 3.0 m or less.

Current Meter. An instrument for measuring the velocity of a current. It is usually operated by a wheel equipped with vanes or cups which is rotated by the action of the impinging current. An indicating or recording device is provided to indicate the speed of rotation which is correlated with the velocity of the current.

Cutoff Wall. A wall at the end of a drainage structure, the top of which is an integral part of the drainage structure. This wall is usually buried and its function is to prevent undermining of the drainage structure if the natural material at the outlet of the structure is dug out by the water discharging from the end of the structure. Cutoff walls are sometimes used at the upstream end of a structure when there is a possibility of erosion at this point.

Debris. Any material including floating woody materials and other trash, suspended sediment, or bed load moved by a flowing stream.

Debris Barrier. A deflector placed at the entrance of a culvert upstream, which tends to deflect heavy floating debris or boulders away from the culvert entrance during high-velocity flow.

Debris Basin. Any area upstream from a drainage structure utilized for the purpose of retaining debris in order to prevent clogging of drainage structures downstream.

Debris Rack. A straight barrier placed across the stream channel which tends to separate light and medium floating debris from stream flow and prevent the debris from reaching the culvert entrance.

Degradation. General and progressive lowering of the longitudinal profile of a channel by erosion.

Design Discharge. The quantity of flow that is expected at a certain point as a result of a design storm. Usually expressed as a rate of flow in cubic meters per second.

Design Flood. The peak discharge (when appropriate, the volume, stage, or wave crest elevation) of the flood associated with the probability of exceedance selected for the design of a highway encroachment. By definition, the highway will not be inundated by the design flood.

Design Frequency. The recurrence interval for hydrologic events used for design purposes. As an example, a design frequency of 50 years means a storm of a magnitude that would be expected to recur on the average of every 50 years. (See Probability of Exceedance.)

Design Storm. That particular storm which contributes runoff which the drainage facilities were designed to handle. This storm is selected for design on the basis of its probability of exceedance or average recurrence interval (See Probability of Exceedance.)

Detention Storage. Surface water moving over the land is in detention storage. Surface water allowed to temporarily accumulate in ponds, basins, reservoirs or other types of holding facility and which is ultimately returned to a watercourse or other drainage system as runoff is in detention storage. (See Retention Storage)

Detritus. Loose material such as; rock, sand, silt, and organic particles.

Dike. Usually an earthen bank alongside and parallel with a river or open channel or an AC dike along the edge of a shoulder. (See Levee)

Dike, Finger. Relatively short embankments constructed normal to a larger embankment, such as an approach fill to a bridge. Their purpose is to impede flow and direct it away from the major embankment.

Dike, Spur. Relatively short embankments constructed at the upstream side of a bridge end for the purpose of aligning flow with the waterway opening and to move scour away from the bridge abutment.

Dike, Toe. Embankment constructed to prevent lateral flow from scouring the corner of the downstream side of an abutment embankment. Sometimes referred to as training dikes.

Dike, Training. Embankments constructed to provide a transition from the natural stream channel or floodplain, both to and from a constricting bridge crossing.

Discharge. A volume of water flowing out of a drainage structure or facility. Measured in cubic meters per second.

Diversion. The change in character, location, direction, or quantity of flow of a natural drainage course. A deflection of flood water is not diversion.

D-Load (Cracking D-Load). A term used in expressing the strength of concrete pipe. The cracking D-load represents the test load required to produce a 0.3 mm crack for a length of 300 mm.

Downdrain. A prefabricated drainage facility assembled and installed in the field for the purpose of transporting water down steep slopes.

Drainage. (1) The process of removing surplus ground or surface water by artificial means. (2) The system by which the waters of an area are removed. (3) The area from which waters are drained; a drainage basin.

Drainage Area (Drainage Basin) (Basin). That portion of the earth's surface upon which falling precipitation flows to a given location. With respect to a highway, this location may be either a culvert, the farthest point of a channel, or an inlet to a roadway drainage system.

Drainage Course. Any path along which water flows when acted upon by gravitational forces.

Drainage Divide. The rim of a drainage basin. A series of high points from which water flows in two directions, to the basin and away from the basin.

Drainage Easement (See Easement).

Drainage System. Usually a system of underground conduits and collector structures which flow to a single point of discharge.

Drawdown. The difference in elevation between the water surface elevation at a constriction in a stream or conduit and the elevation that would exist if the constriction were absent. Drawdown also occurs at changes from mild to steep channel slopes and weirs or vertical spillways.

Dry Weather Flows. A small amount of water which flows almost continually due to lawn watering, irrigation or springs.

Dune. A sand wave of approximately triangular cross section (in a vertical plane in the direction of flow) formed by moving water or wind, with gentle upstream slope and steep downstream slope and deposition on the downstream slope.

Easement. Right to use the land of others.

Eddy Loss. The energy lost (converted into heat) by swirls, eddies, and impact, as distinguished from friction loss.

Encroachment. Extending beyond the original, or customary limits, such as by occupancy of the river and/or flood plain by earth fill embankment.

Endwall. A wall placed at the end of a culvert. It may serve three purposes; one, to hold the embankment away from the pipe and prevent sloughing into the pipe outlet channel; two, to provide a wall which will prevent erosion of the roadway fill; and three, to prevent flotation of the pipe.

Energy Dissipator. A structure for the purpose of slowing the flow of water and reducing the erosive forces present in any rapidly flowing body of water.

Energy Grade Line. The line which represents the total energy gradient along the channel. It is established by adding together the potential energy expressed as the water surface elevation referenced to a datum and the kinetic energy (usually expressed as velocity head) at points along the stream bed or channel floor.

Energy Head. The elevation of the hydraulic grade line at any section plus the velocity head of the mean velocity of the water in that section.

Entrance Head. The head required to cause flow into a conduit or other structure; it includes both entrance loss and velocity head.

Entrance Loss. The head lost in eddies and friction at the inlet to a conduit or structure.

Equalizer. A drainage structure similar to a culvert but different in that it is not intended to pass a design flow in a given direction. Instead it is often placed level so as to permit passage of water in either direction. It is used where there is no place for the water to go. Its purpose is to maintain the same water surface elevation on both sides of the highway embankment.

Erosion. The wearing away of a surface by some external force. In the case of drainage terminology, this term generally refers to the wearing away of the earth's surface by flowing water. It can also refer to the wear on a structural surface by flowing water and the material carried therein.

Erosion and *Scour*. The cutting or wearing away by the forces of water of the banks and bed of a channel in horizontal and vertical directions, respectively.

Erosion and *Accretion.* Loss and gain of land, respectively, by the gradual action of a stream in shifting its channel by cutting one bank while it builds on the opposite bank. Property is lost by erosion and gained by accretion but not by *avulsion* when the shift from one channel to another is sudden. Property is gained by *reliction* when a lake recedes.

Estuary. That portion of a river channel occupied at times or in part by both sea and river flow in appreciable quantities. The water usually has brackish characteristics.

Evaporation. A process whereby water as a liquid is changed into water vapor, typically through heat supplied from the sun.

Fan. A portion of a cone, but sometimes used to emphasize definition of radial channels. Also reference to spreading out of water or soils associated with waters leaving a confined channel.

Fetch. The distance across open water through which wind acts to generate waves.

Flap Gate. This is a form of valve that is designed so that a minimum force is required to push it open but when a greater water pressure is present on the outside of the valve, it remains shut so as to prevent water from flowing in the wrong direction. Construction is simple with a metal cover hanging from an overhead rod or pinion at the end of a culvert or drain.

Flood Frequency. Also referred to as exceedance interval, recurrence interval or return period; the average time interval between actual occurrences of a hydrological event of a given or greater magnitude; the percent chance of occurrence is the reciprocal of flood frequency, e.g., a 2 percent chance of occurrence is the reciprocal statement of a 50-year flood. (See Probability of Exceedance.)

Floodplain. Normally dry land areas subject to periodic temporary inundation by stream flow or tidal overflow. Land formed by deposition of sediment by water; alluvial land.

Floodplain Encroachment. An action within the limits of the base flood plain.

Flood Plane. The position occupied by the water surface of a stream during a particular flood. Also, loosely, the elevation of the water surface at various points along the stream during a particular flood.

Floodproof. To design and construct individual buildings, facilities, and their sites to protect against structural failure, to keep water out or reduce the effects of water entry.

Flood Stage. The elevation at which overflow of the natural banks of a stream begins to cause damage in the reach in which the elevation is measured.

Flood Waters. Former stream waters which have escaped from a watercourse (and its overflow channel) and flow or stand over adjoining lands. They remain as such until they disappear from the surface by infiltration, evaporation, or return to a natural watercourse. They do not become surface waters by mingling with such waters, nor stream waters by eroding a temporary channel.

Flow. A term used to define the movement of water, silt, sand, etc.; discharge; total quantity carried by a stream.

Flow Line. A term used to describe the line connecting the low points in a watercourse.

Flow Regime. The system or order characteristic of streamflow with respect to velocity, depth, and specific energy.

Freeboard. (1) The vertical distance between the level of the water surface usually corresponding to the design flow and a point of interest such as a bridge beam, levee top or specific location on the roadway grade. (2) The distance between the normal operating level and the top of the sides of an open conduit; the crest of a dam, etc., designed to allow for wave action, floating debris, or any other condition or emergency, without overtopping the structure.

Free Outlet. A condition under which water discharges with no interference such as a pipe discharging into open air.

Free Water. Water which can move through the soil by force of gravity.

French Drain. A trench loosely backfilled with stones, the largest stones being placed in the bottom with the size of stones decreasing towards the top. The interstices between the stones serve as a passageway for water.

Froude Number. A dimensionless expression of the ratio of inertia forces to gravity forces, used as an index to characterize the type of flow in a hydraulic structure in which gravity is the force producing motion and inertia is the resisting force. It is equal to a characteristic flow velocity (mean, surface, or maximum) of the system divided by the square root of the product of a characteristic dimension (as diameter of depth) and the gravity constant (acceleration due to gravity) all expressed in consistent units. $F_r = V/(gy)^{1/2}$

Gaging Station. A location on a stream where measurements of stage or discharge are customarily made. The location includes a reach of channel through which the flow is uniform, a control downstream from this reach and usually a small building to house the recording instruments.

Grade to Drain. A construction note often inserted on a plan for the purpose of directing the Contractor to slope a certain area in a specific direction, so that the surface waters will flow to a designated location.

Gradient (Slope). The rate of ascent or descent expressed as a percent or as a decimal as determined by the ratio of the change in elevation to the length.

Gradually Varied Flow. In this type of flow, changes in depth and velocity take place slowly over large distances, resistance to flow dominates and acceleration forces are neglected.

Ground Water. That water which is present under the earth's surface. Ground water is that situated below the surface of the land, irrespective of its source and transient status. Subterranean streams are flows of ground waters parallel to and adjoining stream waters, and usually determined to be integral parts of the visible streams.

Head. Represents an available force equivalent to a certain depth of water. This is the motivating force in effecting the movement of water. The height of water above any point or plane of reference. Used also in various compound expressions, such as energy head, entrance head, friction head, static head, pressure head, lost head, etc.

Headcutting. Progressive scouring and degrading of a streambed at a relatively rapid rate in the upstream direction, usually characterized by one or a series of vertical falls.

Hydraulic Gradient. A line which represents the relative force available due to the potential energy available. This is a combination of energy due to the height of the water and the internal pressure. In any open channel, this line corresponds to the water surface. In a closed conduit, if several openings were placed along the top of the pipe and open tubes inserted, a line connecting the water surface in each of these tubes would represent the hydraulic grade line.

Hydraulic Jump (or Jump). Transition of flow from the rapid to the tranquil state. A varied flow phenomenon producing a rise in elevation of water surface. A sudden transition from supercritical flow to the complementary subcritical flow, conserving momentum and dissipating energy.

Hydraulic Mean Depth. The area of the flow cross section divided by the water surface width.

Hydraulic Radius. The cross sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit; the ratio of area to wetted perimeter.

Hydrograph. A graph showing stage, flow, velocity, or other property of water with respect to time.

Hydrography. Water Surveys. The art of measuring, recording, and analyzing the flow of water; and of measuring and mapping watercourses, shore lines, and navigable waters.

Hydrology. The science dealing with the occurrence and movement of water upon and beneath the land areas of the earth. Overlaps and includes portions of other sciences such as meteorology and geology. The particular branch of Hydrology that a design engineer is generally interested in is surface runoff which is the result of excessive precipitation.

Hyetograph. Graphical representation of rainfall intensity against time.

Incised Channel. Those channels which have been cut relatively deep into underlying formations by natural processes. Characteristics include relatively straight alignment and high, steep banks such that overflow rarely occurs, if ever.

Infiltration. The passage of water through the soil surface into the ground.

Inlet Time. The time required for storm runoff to flow from the most remote point, in flow time, of a drainage area to the point where it enters a drain or culvert.

Inlet Transition. A specially shaped entrance to a box or pipe culvert. It is shaped in such a manner that in passing from one flow condition to another, the minimum turbulence or interference with flow is permitted.

Inundate. To cover with a flood.

Invert. The bottom of a drainage facility along which the lowest flows would pass.

Invert Paving. Generally applies to metal pipes where it is desirable to improve flow characteristics or prevent corrosion at low flows. The bottom portion of the pipe is paved with an asphaltic material, concrete, or air-blown mortar.

Inverted Siphon. A pipe for conducting water beneath a depressed place. A true inverted siphon is a culvert which has the middle portion at a lower elevation than either the inlet or the outlet and in which a vacuum is created at some point in the pipe. A sag culvert is similar, but the vacuum is not essential to its operation.

Isohyetal Line. A line drawn on a map or chart joining points that receive the same amount of precipitation.

Isohyetal Map. A map containing isohyetal lines and showing rainfall intensities.

Isovel. Line on a diagram of a channel connecting points of equal velocity.

Jack (or Jack Straw). Bank protection element consisting of wire or cable strung on three mutually perpendicular struts connected at their centers.

Jacking Operations. A means of constructing a pipeline under a highway without open excavation. A cutting edge is placed on the first section of pipe and the pipe is forced ahead by hydraulic jacks. As the leading edge pushes ahead, the material inside the pipe is dug out and transported outside the pipe for disposal.

Jetty. An elongated, artificial obstruction projecting into a stream or the sea from bank or shore to control shoaling and scour by deflection of strength of currents and waves.

Lag. Variously defined as time from beginning (or center of mass) of rainfall to peak (or center of mass) of runoff.

Laminar Flow. That type of flow in which each particle moves in a direction parallel to every other particle and in which the head loss is approximately proportional to the velocity (as opposed to turbulent flow).

Lateral. In a roadway drainage system, a drainage conduit transporting water from inlet points to the main drain trunk line.

Levee. An embankment to prevent inundation. (See Dike)

Local Depression. A low area in the pavement or in the gutter established for the special purpose of collecting surface waters on a street and directing these waters into a drainage inlet.

Maximum Historical Flood. The maximum flood that has been recorded or experienced at any particular highway location.

Mean Annual Flood. The flood discharge with a recurrence interval of 2.33 years.

Meander. In connection with streams, a winding channel usually in an erodible, alluvial valley. A reverse or S-shaped curve or series of curves formed by erosion of the concave bank, especially at the downstream end, characterized by curved flow and alternating shoals and bank erosions. Meandering is a stage in the migratory movement of the channel, as a whole, down the valley.

Meander Plug (Clay Plug). Deposits of cohesive materials in old channel bendways. These plugs are sufficiently resistant to erosion to serve as essentially semi-permanent geological controls to advancing channel migrations.

Meander Scroll. Evidence of historical meander patterns in the form of lines visible on the inside of meander bends (particularly on aerial photographs) which resemble a spiral or convoluted form in ornamental design. These lines are concentric and regular forms in high sinuosity channels and are largely absent in poorly developed braided channels.

Mud Flow. A well-mixed mass of water and alluvium which, because of its high viscosity, and low fluidity as compared with water, moves at a much slower rate, usually piling up and spreading out like a sheet of wet mortar or concrete.

Natural and Beneficial Floodplain Values. Includes but are not limited to fish, wildlife, plants, open space, natural beauty, scientific study, outdoor recreation, agriculture, aquaculture, forestry, natural moderation of floods, water quality maintenance, and groundwater recharge.

Navigable Waters. Those stream waters lawfully declared or actually used as such. Navigable Waters of the State of California are those declared by Statute. Navigable Waters of the United States are those determined by the Corps of Engineers or the U.S. Coast Guard to be so used in interstate or international commerce. Other streams have been held navigable by courts under the common law that navigability in fact is navigability in law.

Negative Projecting Conduits. A structure installed in a trench with the top below the top of trench, then covered with backfill and embankment. See Positive Projecting Conduit

Nonuniform Flow. A flow in which the velocities vary from point to point along the stream or conduit, due to variations in cross section, slope, etc.

Normal Depth. The depth at which flow is steady and hydraulic characteristics are uniform.

Normal Water Surface (Natural Water Surface). The free surface associated with flow in natural streams.

"n" Value. The roughness coefficient in the Manning formula for determination of the discharge coefficient in the Chezy formula,

$$V = C(RS)^{1/2}, \text{ where } C = \left(\frac{1}{n}\right)R^{1/6}$$

Off-Site Drainage. The handling of that water which originates outside the highway right of way.

On-Site Drainage. The handling of that water which originates inside the highway right of way.

Open Channel. Any conveyance in which water flows with a free surface.

Ordinary High Water Mark. The line on the shore established by the fluctuation of water and physically indicated on the bank ($1.5 \pm$ years return period)

Outfall. Discharge or point of discharge of a culvert or other closed conduit.

Outwash. Debris transported from a restricted channel to an unrestricted area where it is deposited to form an alluvial or debris cone or fan.

Overtopping Flood. The flood described by the probability of exceedance and water surface elevation at which flow occurs over the highway, over the watershed divide, or through structure(s) provided for emergency relief.

Peak Flow. Maximum momentary stage or discharge of a stream in flood. Design Discharge.

Perched Water. Ground water located above the level of the water table and separated from it by a zone of impermeable material.

Percolating Waters. Waters which have infiltrated the surface of the land and move slowly downward and outward through devious channels (aquifers) unrelated to stream waters, until they reach an underground lake or regain and spring from the land surface at a lower point.

Permeability. The property of soils which permits the passage of any fluid. Permeability depends on grain size, void ratio, shape and arrangement of pores.

Physiographic Region. A geographic area whose pattern of landforms differ significantly from that of adjacent regions.

Piping. The action of water passing through or under an embankment and carrying some of the finer material with it to the surface at the downstream face.

Point of Concentration. That point at which the water flowing from a given drainage area concentrates. With reference to a highway, this would generally be either a culvert entrance or some point in a roadway drainage system.

Poised Stream. A term used by river engineers applying to a stream that over a period of time is neither degrading or aggrading its channel, and is nearly in equilibrium as to sediment transport and supply.

Positive Projecting Conduit. A structure installed in shallow trench with the top of the conduit projecting above the top of the trench and then covered with embankment. See Negative Projecting Conduit.

Potamology. The hydrology of streams.

Practicable. Capable of being done within reasonable natural, social, and economic constraints.

Precipitation. Rainfall, snow, sleet, fog, hail, dew and frost.

Prescriptive Rights. The operation of the law whereby rights may be established by long exercise of their corresponding powers or extinguished by prolonged failure to exercise such powers.

Preserve. To avoid modification to the functions of the natural floodplain environment or to maintain it, as closely as practicable, in its natural state.

Probability of Exceedance. The statistical probability, expressed as a percentage, of a hydrologic event occurring or being exceeded in any given year. The probability (p) of a storm or flood is the reciprocal of the average recurrence interval (N).

Probable Maximum Flood. The flood discharge that may be expected from the most severe combination of critical meteorological and hydrological conditions that are reasonably possible in the region.

Pumping Plant. A complete pumping installation including a storage box, pump or pumps, standby pumps, connecting pipes, electrical equipment, pumphouse and outlet chamber.

Rainfall. Point Precipitation: That which registers at a single gauge. Area Precipitation: Adjusted point rainfall for area size.

Rainwash. The creep of soil lubricated by rain.

Rapidly Varied Flow. In this type of flow, changes in depth and velocity take place over short distances, acceleration forces dominate, and energy loss due to friction is minor.

Reach. The length of a channel uniform with respect to discharge, depth, area, and slope. More generally, any length of a river or drainage course.

Regime. The system or order characteristic of a stream; its behavior with respect to velocity and volume, form of and changes in channel, capacity to transport sediment, amount of material supplied for transportation, etc.

Regimen. The characteristic behavior of a stream during ordinary cycles of flow.

Regulatory Floodway. The open floodplain area that is reserved in by Federal, State, or local requirements, i.e., unconfined or unobstructed either horizontally or vertically, to provide for the discharge of the base flood so that the cumulative increase in water surface elevation is no more than a designated amount (not to exceed 0.3048 m as established by the Federal Emergency Management Agency (FEMA) for administering the National Flood Insurance Program (NFIP)).

Reliction. Pertaining to being left behind. For example: that area of land is left behind by reliction when the water surface of a lake is lowered.

Restore. To reestablish a setting or environment in which the functions of the natural and beneficial floodplain values adversely impacted by the highway agency can continue to operate.

Retarding Basin. Either a natural or man made basin with the specific function of delaying the flow of water from one point to another. This tends to increase the time that it takes all the water falling on the extremities of the drainage basin to reach a common point, resulting in a reduced peak flow at that point.

Retention Storage. Water which accumulates and ponds in natural or excavated depressions in the soil surface with no possibility for escape as runoff. (See Detention Storage)

Retrogression. Reversal of stream grading; i.e., aggradation after degradation, or vice versa.

Revetment. Bank protection to prevent erosion.

Riparian. Pertaining to the banks of a stream.

Riprap. Protection against erosion consisting of broken concrete, sacked concrete, rock, etc.

Ripple. (1) The light fretting or ruffling of a water caused by a breeze. (2) Undulating ridges and furrows, or crests and troughs formed by action of the flow.

Risk. The consequences associated with the probability of flooding attributable to an encroachment. It includes the potential for property loss and hazard to life during the service life of the highway.

Risk Analysis. An economic comparison of design alternatives using expected total costs (construction costs plus risk costs) to determine the alternative with the least expected cost to the public. It must include probable flood-related costs during the service life of the facility for highway operation, maintenance, and repair, for highway aggravated flood damage to other property, and for additional or interrupted highway travel.

Riser. In mountainous terrain where much debris is encountered, the entrance to a culvert sometimes becomes easily clogged. Therefore, a corrugated metal pipe or a structure made of timber or concrete with small perforations, called a riser, is installed vertically to permit entry of water and prohibit the entry of mud and debris. The riser may be increased in height as the need occurs.

Rounded Inlet. The edges of a culvert entrance that are rounded for smooth transition which reduces turbulence and increases capacity.

Runoff. The portion of precipitation that appears as flow in streams. Drainage or flood discharge which leaves an area as surface flow or a pipeline flow, having reached a channel or pipeline by either surface or subsurface routes.

Sag Culvert (or Sag Pipe). A pipeline with a dip in its grade line crossing over a depression or under a highway, railroad, canal, etc. The term inverted siphon is common but inappropriate as no siphonic action is involved. The term "sag pipe" is suggested as a substitute.

Scour. The result of erosive action of running water, primarily in streams, excavating and carrying away material from the bed and banks. Wearing away by abrasive action.

Scour, General. The removal of material from the bed and banks across all or most of the width of a channel, as a result of a flow contraction which causes increased velocities and bed shear stress.

Scour, Local. Removal of material from the channel bed or banks which is restricted to a minor part of the width of a channel. This scour occurs around piers and embankments and is caused by the actions of vortex systems induced by the obstruction to the flow.

Scour, Natural. Removal of material from the channel bed or banks which occurs in streams with the migration of bed forms, shifting of the thalweg and at bends and natural contractions.

Sediment. Fragmentary material that originates from weathering of rocks and is transported by, suspended in, or deposited by water.

Sedimentation. Gravitational deposit of transported material in flowing or standing water.

Seismic Wave. A gravity wave caused by an earthquake.

Sheet Flow. Any flow spread out and not confined; i.e., flow across a flat open field.

Shoaling. Deposition of alluvial material resulting in areas with relatively shallow depth.

Significant Encroachment. A highway encroachment and any direct support of likely base floodplain development that would involve one or more of the following construction or flood related impacts:

- A significant potential for interruption or termination of a transportation facility which is needed for emergency vehicles or provides a community's only evacuation route.
- A significant risk, or
- A significant adverse impact on natural and beneficial floodplain values.

Silt. (1) *Water-Borne Sediment.* Detritus carried in suspension or deposited by flowing water, ranging in diameter from 0.005 to 0.05 mm. The term is generally confined to fine earth, sand, or mud, but is sometimes both suspended and bedload. (2) *Deposits of Water-Borne Material.* As in a reservoir, on a delta, or on floodplains.

Sinuosity. The ratio of the length of the river thalweg to the length of the valley proper.

Skew. When a drainage structure is not normal (perpendicular) to the longitudinal axis of the highway, it is said to be on a skew. The skew angle is the smallest angle between the perpendicular and the axis of the structure.

Slide. Gravitational movement of an unstable mass of earth from its natural position.

Slipout. Gravitational movement of an unstable mass of earth from its constructed position. Applied to embankments and other man-made earthworks.

Slope. (1) Gradient of a stream. (2) Inclination of the face of an embankment, expressed as the ratio of horizontal to vertical projection; or (3) The face of an inclined embankment or cut slope. In hydraulics it is expressed as percent or in decimal form.

Slough. (1) Pronounced SLU. A side or overflow channel in which water is continually present. It is stagnant or slack; also a waterway in a tidal marsh. (2) Pronounced SLUFF. Slide or slipout of a thin mantle of earth, especially in a series of small movements.

Slugflow. Flow in culvert or drainage structure which alternates between full and partly full. Pulsating flow -- mixed water and air.

Soffit. The bottom of the top -- (1) With reference to a bridge, the low point on the underside of the suspended portion of the structure. (2) In a culvert, the uppermost point on the inside of the structure.

Specific Energy. The energy contained in a stream of water, expressed in terms of head, referred to the bed of a stream. It is equal to the mean depth of water plus the velocity head of the mean velocity.

Stage. The elevation of a water surface above its minimum; also above or below an established "low water" plane; hence above or below any datum of reference; gage height.

Standing Wave. A term which when used to describe the upper flow regime in alluvial channels, means a vertical oscillation of the water surface between fixed nodes without appreciable progression in either an upstream or downstream direction. To maintain the fixed position, the wave must have a celerity (velocity) equal to the approach velocity in the channel, but in the opposite direction.

Steady Flow. A flow in which the flow rate or quantity of fluid passing a given point per unit of time remains constant.

Storage. Detention, or retention of water for future flow, naturally in channel and marginal soils or artificially in reservoirs.

Storage Basin. Space for detention or retention of water for future flow, naturally in channel and marginal soils, or artificially in reservoirs.

Storm. A disturbance of the ordinary, average conditions of the atmosphere which, unless specifically qualified, may include any or all meteorological disturbances, such as wind, rain, snow, hail, or thunder.

Storm Drain. That portion of a drainage system expressly for collecting and conveying former surface water in an enclosed conduit. Often referred to as a "storm sewer", storm drains include inlet structures, conduit, junctions, manholes, outfalls and other appurtenances.

Storm Water Management. The recognition of adverse drainage resulting from altered runoff and the solutions resulting from the cooperative efforts of public agencies and the private sector to mitigate, abate, or reverse those adverse results.

Stream Power. An expression used in predicting bed forms and hence bed load transport in alluvial channels. It is the product of the mean velocity, the specific weight of the water-sediment mixture, the normal depth of flow and the slope.

Stream Response. Changes in the dynamic equilibrium of a stream by any one, or combination of various causes.

Stream Waters. Former surface waters which have entered and now flow in a well defined natural watercourse, together with other waters reaching the stream by direct precipitation or rising from springs in bed or banks of the watercourse. They continue as stream waters as long as they flow in the watercourse, including overflow and multiple channels as well as the ordinary or low-water channel.

Strutting. Elongation of the vertical axis of pipe prior to installing in a trench. After the backfill has been placed around the pipe and compacted, the wires or rods holding the pipe in its distorted shape are removed. Greater side support from the earth is developed when the pipe tends to return to its original shape. Generally used on pipes which because of size or thinness of the metal would tend to deform during construction operations. Arches are strutted diagonally per standard or special plan.

Subcritical Flow. In this state, gravity forces are dominant, so that the flow has a low velocity and is often described as tranquil and streaming. Also, that flow which has a Froude number less than one.

Subdrain. A conduit for collecting and disposing of underground water. It generally consists of a pipe, with perforations in the bottom through which water can enter.

Sump. In drainage, any low area which does not permit the escape of water by gravity flow.

Supercritical Flow. In this state, inertia forces are dominant, so that flow has a high velocity and is usually described as rapid, shooting and torrential. Also, that flow which has a Froude number greater than one.

Support Base Floodplain Development. To encourage, allow, serve, or otherwise facilitate additional base floodplain development. Direct support results from an encroachment, while indirect support results from an action out of the base floodplain.

Surface Runoff. The movement of water on earth's surface, whether flow is over surface of ground or in channels.

Surface Waters. Surface waters are those which have been precipitated on the land from the sky or forced to the surface in springs, and which have then spread over the surface of the ground without being collected into a definite body or channel. They appear as puddles, sheet or overland flow, and rills, and continue to be surface waters until they disappear from the surface by infiltration or evaporation, or until by overland or vagrant flow they reach well-defined watercourses or standing bodies of water like lakes or seas.

Suspended Load. Sediment that is supported by the upward components of turbulent currents in a stream and that stay in suspension for appreciable amount of time.

Swale. A shallow, gentle depression in the earth's surface. This tends to collect the waters to some extent and is considered in a sense as a drainage course, although waters in a swale are not considered stream waters.

Tapered Inlet. A transition to direct the flow of water into a channel or culvert. A smooth transition to increase hydraulic efficiency of an inlet structure.

Thalweg. The line following the lowest part of a valley, whether under water or not. Usually the line following the deepest part of the bed or channel of a river.

Time of Concentration. The time required for storm runoff to flow from the most remote point, in flow time, of a drainage area to the point under consideration. It is usually associated with the design storm.

Trash Rack. A grid or screen across a stream designed to catch floating debris.

Trunk (or Trunk Line). In a roadway drainage system, the main conduit for transporting the storm waters. This main line is generally quite deep in the ground so that laterals coming from fairly long distances can drain by gravity into the trunk line.

Tsunami. A gravity wave caused by an underwater seismic disturbance (such as sudden faulting, landsliding or volcanic activity).

Turbulence. A state of flow wherein the water is agitated by cross-currents and eddies, as opposed to a condition of flow that is quiet and laminar.

Turbulent Flow. That type of flow in which any particle may move in any direction with respect to any other particle, and in which the head loss is approximately proportional to the square of the velocity.

Undercut. Erosion of the low part of a steep bank so as to compromise stability of the upper part.

Underflow. The downstream flow of water through the permeable deposits that underlie a stream. (1) Movement of water through a pervious subsurface stratum, the flow of percolating water; or water under ice, or under a structure. (2) The rate of flow or discharge of subsurface water.

Unsteady Flow. A flow in which the velocity changes with respect to space and time.

Velocity Head. A term used in hydraulics to represent the kinetic energy of flowing water. This "head" is represented by a column of standing water equivalent in potential energy to the kinetic energy of the moving water calculated as $(V^2/2g)$ where the "V" represents the velocity in meters per second and "g" represents the potential acceleration due to gravity, in meters per second per second.

Watercourse. A definite channel with bed and banks within which water flows, either continuously or in season. A watercourse is continuous in the direction of flow and may extend laterally beyond the definite banks to include overflow channels contiguous to the ordinary channel. The term does not include artificial channels such as canals and drains, except natural channels trained or restrained by the works of man. Neither does it include depressions or swales through which surface or errant waters pass.

Watershed. The area drained by a stream or stream system.

Water Table. The surface of the groundwater below which the void spaces are completely saturated.

Waterway. That portion of a watercourse which is actually occupied by water.

Weephole. A hole in a wall, invert, apron, lining, or other solid structure to relieve the pressure of groundwater.

Weir. A low overflow dam or sill for measuring, diverting, or checking flow.

Topic 807 - Selected Drainage References

807.1 Introduction

Hydraulic and drainage related reference publications listed are grouped as to source.

807.2 Federal Highway Administration Hydraulic Publications

Copies of publications identified with an NTIS or GPO number may be ordered as follows:

- NTIS - Send a check to:

  National Technical Information Service
  5285 Port Royal Road
  Springfield, VA 22161
  (703) 487-4650

- GPO - Send a check to:

  Superintendent of Documents
  Government Printing Office
  Washington, D.C. 20402
  (202) 783-3238

(1) Hydraulic Engineering Circulars (HEC).

HEC No.	Title	Date	FHWA # NTIS #
1	Selected Bibliography of Hydraulic and Hydrologic Subjects	1983	EPD-86-104 PB86-179256/AS
9	Debris-Control Structures	1971	EPD-86-106 PB86-179801/AS
10	Capacity Charts for the Hydraulic Design of Highway Culverts	1972	EPD-86-107 PB86-185691/AS
11	Design of Riprap Revetment	1989	IP-89-016 PB86-179793/AS
12	Drainage of Highway Pavements (GPO 050-001-00280-9)	1984	TS-84-202 PB84-215003/AS
14	Hydraulic Design of Energy Dissipators for Culverts and Channels	1983	EPD-86-110 PB86-180205/AS
15	Design of Roadside Channels with Flexible Linings	1988	IP-87-7 PB89-122584/AS
16	Addendum to Highways in the River Environment	1980	EPD-86-116 PB86-178852/AS
17	The Design of Encroachments on Flood Plains Using Risk Analysis	1981	EPD-86-112 PB86-182110/AS
18	Evaluating Scour at Bridges	1993	IP-90-017 PB91-198739
19	Hydrology	1984	IP-84-15 PB85-182954
20	Stream Stability at Highway Structures	1991	IP-90-014 PB91-198788
21	Bridge Deck Drainage Systems	1993	SA-92-010

(2) Hydraulic Design Series (HDS).

HDS No.	Title	Date	FHWA # NTIS #
1	Hydraulics of Bridge Waterways	1978	EPD-86-101 PB86-181708/AS
3	Design Charts for Open-Channel Flow	1961	EPD-86-102 PB86-179249/AS
4	Design of Roadside Drainage Channels	1965	EPD-86-103 PB86-180288/AS
5	Hydraulic Design of Highway Culverts (GPO 050-001-00298-1)	1985	IP-85-15 PB86-196961/AS

(3) Implementation Publications.

	Title	Date	FHWA # NTIS #
o	Highways in the River Environment	1990	FHWA-Hi-90-016
o	Design of Urban Highway Drainage	1979	TS-79-225 PB83-259903
o	Highways and Wetlands	1980	IP-80-11
-	Vol 1, Interim Procedural Guidelines		PB81-242083
-	Vol 2, Impact Assessment		PB81-242091
-	Vol 3, Annotated Bibliography		PB81-242109
o	Hydraulic Flow Resistance Factors for Corrugated Metal Conduits	1980	TS-80-216 PB84-103811
o	Underground Disposal of Storm Water Runoff, Design Guidelines Manual	1980	TS-80-218 PB83-180257
o	Manual for Highway StormWater Pumping Stations,Vol 1 & 2 (Appendices)	1982	IP-82-17 PB84-152727 & PB84-152785
o	Structural Design Manual for Improved Inlets and Culverts	1983	IP-83-6 PB84-153485
o	Guide for Selecting Manning's Roughness Coefficient for Natural Channels and Flood Plains	1984	TS-84-204 PB84-242585
o	Culvert Inspection Manual	1986	IP-86-2 PB87-151809
o	Use of Riprap for Bank Protection	1986	TS-86-211 PB86-217197

(4) Research Publications.

	Title	Date	FHWA # NTIS #
o	Approximate Method for Computing Backwater Profiles in Corrugated Metal Pipes	1976	RD-76-42 PB76-263915
o	Countermeasures for Hydraulic Problems at Bridges	1978	
-	Vol 1, Analysis and Assessment	1978	RD-78-162 PB79-297132
-	Vol 2, Case Histories for Sites 1-283	1981	RD-78-163 PB79-297685
o	Constituents of Highway Runoff		
-	Vol 1, State-of-the-art Report	1981	RD81-042 PB81-1241895
-	Vol 2, Procedure Manual for Monitoring	1981	RD-81-043 PB81-1241903
-	Vol 3, Predictive Procedures	1981	RD-81-044 PB81-1241911
-	Vol 4, Characteristics of Highway Runoff		RD-81-045 PB81-1241929
-	Vol 5, Data Storage Prg.	1981	RD-81-046 PB81-1241937
-	Vol 6, Executive Summary	1981	RD-81-047 PB81-1241945
o	Streambank Stabilization Measures for Highway Stream Crossings, Executive Summary	1985	RD-84-099 PB86-186848/AS
o	Streambank Stabilization Measures for Highway Engineers	1985	RD-84-100 PB86-187986/AS

o Design of Spur-Type Streambank Stabilization Structures	1985	RD-84-101 PB86-186830/AS
o Retention, Detention, and Overland Flow for Pollutant Removal	1988	RD-87-056 PB89-133292/AS
o Minimizing Embankment Damages During Overtopping	1990	RD-88-181 PB90-266107
o Cost-Effective Roadway Drainage Design using EconomicAnalysis	1990	RD-88-126 PB90-104497

(5) HYDRAIN - Integrated Drainage Design Computer System

The pool-funded project to develop the HYDRAIN computer system has essentially been completed (only metric conversion remains) with the release of version 5.0 in 1994. All seven volumes listed below are contained in report No. FHWA-RD-92-061.

Volume No.	Title
I	HYDRAIN - System Shell
II	HYDRO - Hydrology
III	HYDRA Storm Drains
IV	HYCLV - Culvert Design & Analysis
V	WSPRO - Step Backwater & Bridge Hydraulics
VI	HY8 - Culvert Analysis
VII	HYCHL - Channel Stability

807.3 American Association of State Highway and Transportation Officials (AASHTO)

(1) Highway Drainage Guidelines

The Drainage Guidelines is a collection of the guides previously published as individual volumes. These are:

I - Hydraulic Considerations in Highway Planning and Location

II - Hydrology

III - Erosion and Sediment Control in Highway Construction

IV - Hydraulic Design of Culverts

V - The Legal Aspects of Highway Drainage

VI - Hydraulic Analysis and Design of Open Channels

VII - Hydraulic Analysis for the Location and Design of Bridges

VIII - Hydraulic Aspects in Restoration and Upgrading of Highways

IX - Storm Drain Systems

X - Evaluating Highway Effects on Surface Water Environments

XI - Highways along Coastal Zones and Lakeshores

The current edition may be purchased through AASHTO, 444 North Capitol St., N.W., Suite 225, Washington D.C. 20001.

(2) AASHTO Model Drainage Manual

The Model Drainage Manual (MDM) is a comprehensive document covering a wide variety of transportation related hydraulic design issues. Developed for use by Federal, State, and local agencies, the MDM is a practice oriented document that allows the user agency to adopt the recommended values shown in the manual, or insert their own specific design policies and procedures.

807.4 California Department of Transportation

The following publications are available from the Caltrans Publications Unit, 1900 Royal Oaks Dr., Sacramento, CA 95815. Information on ordering and price can be checked by calling (916) 445-3520.

- Bridge Design Practice Manual
- Manual of Test - Volumes 1, 2, and 3
- Standard Plans
- Standard Specifications

The following reports have been published by METS, 5900 Folsom Blvd., P.O. Box 19128, Sacramento, CA 95819. Information on availability and price can be checked by calling (916) 227-7114.

- Infiltration Drainage of Highway Surface Water, 1980, Report No. FHWA/CA/TL-80/04.
- Evaluation of Brush Layering, 1985.
- CULVERT3.EXE, (4-16-94) Computer Program to calculate maintenance-free service life using California Culvert Criteria.

807.5 U.S. Department of Interior - Geological Survey (USGS)

- Magnitude and Frequency of Floods in California - Water Resources Investigation 77-21.
- Water Resources Data for California, Part 1, Volumes 1 and 2.
- Rock Riprap Design for Protection of Stream Channels Near Highway Structures (1987) Volumes 1 and 2 (1987).

807.6 U.S. Department of Agriculture - Soil Conservation Service (SCS)

- Engineering Design Standards.

807.7 California Department of Water Resources and Caltrans

- Rainfall Intensity - Duration - Frequency Computer Program (Available through Caltrans).

807.8 University of California - Institute of Transportation and Traffic Engineering (ITTE)

- Street and Highway Drainage - Course Notes, Volumes 1 and 2.

807.9 U.S. Army Corps of Engineers

Publications and computer programs, too numerous to list, are available from the Water Resources Support Center. A publication catalog may be obtained by contacting the Hydrologic Engineering Center of the Corp, 609 Second St., Davis, CA 95616.